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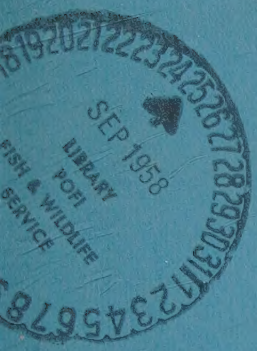

SCOTTISH HOME DEPARTMENT

Marine Research
1958 No. 4

The Occurrence of Plerocercoid Larvae of *Grillotia erinaceus* (van Beneden) in Halibut

By BENNET B. RAE, M.A., B.Sc., Ph.D.

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The Occurrence of Plerocercoid Larvae of *Grillotia erinaceus* (van Beneden) in Halibut

INTRODUCTION

More than a hundred years ago P. J. van Beneden (1850) described encysted cestode larvae from flesh of cod, *Gadus callarias*, L., and angler, *Lophius piscatorius*, L., under the name of *Tetrarhynchus aceus*. A few years later (1858) the same author gave an account of the adult worm which he found in gut of various species of rays. Although subsequent references to this parasite have appeared in ntific literature, James Johnstone (1912) appears to have been the first to describe it in detail and lemonstrate its presence in halibut *Hippoglossus hippoglossus* (L.). His researches confirmed that skates l rays act as hosts to the sexually mature worm and showed that a larval stage, the plerocercoid, is ndant in the stomach wall and mesenteries of a number of the common food-fishes in the Irish Sea. also revealed that, exceptionally, the same larval stage may be found in the muscle tissues or flesh alibut and hake *Merluccius merluccius* (L.).

Johnstone concluded that the plerocercoid stage in teleost fishes represented only part of the parasite's al life and that a younger stage was probably to be found in some invertebrate. He also came to the clusion, and found support for his findings in the work of Southwell (1911) on similar worms in fishes ght off the coast of Ceylon, that the encysted stage in teleosts is not an essential part of the parasite's cycle but represents a development along a cul-de-sac. His reasons for this view were first the diffi- ty of transmission of the parasite from many teleosts such as large halibut to the adult host and secondly presence of numerous degenerate cysts containing only calcareous corpuscles with some connective ue.

The investigations carried out by Johnstone were undertaken as a result of a series of condemnations halibut by local health inspectors at west of England ports in 1906. It is interesting, therefore, to ord that the investigations now being described were also undertaken following a similar series of demnations of halibut during the summer of 1952. In this case the fish had been consigned from erdeen to English markets and, as a result of the usual practice of transporting this species whole, worm-infested condition was not discovered until the fish were cut up by the retailers.

Preliminary inspections of halibut on Aberdeen fish market, which were instituted immediately, ealed the presence of small, white, circular or oval-shaped cysts in the lining of the body cavity of tain fish. Furthermore, in specimens procured for internal examination, infestation of the flesh was covered in a number of instances—generally in fish already exhibiting severe infestation of the body ity. The identification of the parasite was confirmed by officers of the British Museum (Natural tory) as the plerocercoid larva of *Grillotia erinaceus* (van Beneden)—the older generic name of *Tetrar- chus* having been superseded in the course of years by *Grillotia*.

The potential threat to the economy of a section of the halibut trade was at once recognised and os were taken to investigate the problem. In view of its urgency two immediate objectives were set:

1. The location of the grounds from which infested fish were originating.
2. The determination of some quick yet dependable method of recognising halibut with infestation of the flesh on the market floor.

SOURCE OF MATERIAL AND COLLECTION OF DATA

Investigations were started in Aberdeen fish market in July 1952 and continued intermittently until y 1953. From the latter date a regular daily inspection of halibut by members of the staff of the City

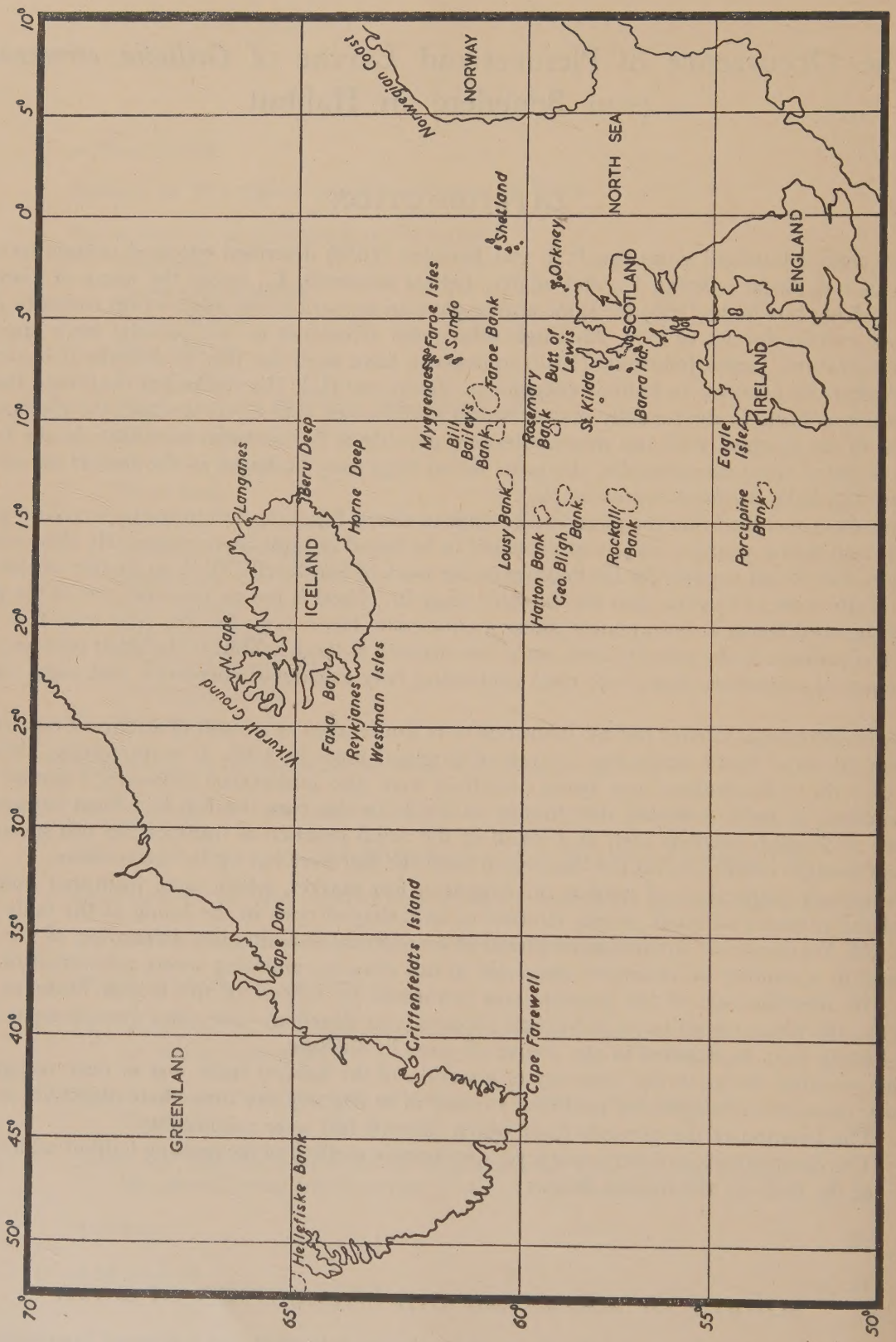

Fig. 1 Chart of North Atlantic halibut grounds.

Aberdeen Health Department was organised on the market. The author therefore wishes to acknowledge assistance given by Mr. S. Hogg and latterly by Mr. S. Howell and Mr. F. Mair and to thank Dr. A. MacQueen, the Medical Officer of Health, for permission to include records accumulated by his ff. Appreciation must also be expressed to all sections of the fishing industry and fish trade for their ling co-operation throughout the investigations. This paper includes results up to the end of 1956.

At first all sizes of halibut, both trawl- and line-caught, were sampled from all the different grounds lding this species. It soon became obvious, however, that the smallest size of halibut, the trawl-caught ickens' of up to 20 inches (approximately 51 cm) in length, were not affected and accordingly in- ction of these was curtailed. Relatively few of this category are, therefore, included in the totals mined. From the outset distinction was drawn between fish of less than 3 feet (approximately 91 cm) ength and those of 3 feet and over. This dividing point was chosen, somewhat arbitrarily, as repre- ting a convenient average measurement separating the immature and adolescent from the mature adult fish. As the work proceeded it became clear that halibut on certain grounds were completely from infestation. This permitted a relaxation of the sampling of these grounds and a concentration effort on the affected grounds. At the same time it gradually became obvious that only a small per- tage of fish of less than 3 feet in length was infested so that it was possible to concentrate the examination further on fish of 3 feet and over with the result that by the end of 1953 all halibut in this category n all the affected grounds were inspected before being sold on the market.

The following routine was observed throughout the investigations. Examination of the halibut was ried out on Aberdeen fish market early in the morning after the discharging of the vessels but before sale of the fish by auction. Frequently this entailed rapid work under conditions which varied con- rably according to the time of year, the state of the market, the number of catches to be inspected, size of the fish, etc. The fishing grounds and means of capture were usually ascertained first of all, the size grouping of the fish determined either by measurement or assessment. The body cavity of h fish was then scrutinized for the presence of cysts. At the same time the open surfaces of the flesh he 'flaps' exposed in gutting operations were also examined. If worm cysts were found to be present he body cavity the degree of infestation was noted. This was decided as light, moderate or heavy ording to certain visual standards determined during the preliminary stages of the work (Figures nd 3). The general size and appearance of the cysts and their distribution within the body cavity were noted. As Scottish fishermen frequently do not remove the gonads in gutting, numerous notes were le on the state of maturity of the fish examined.

All halibut showing moderate or heavy infestation of the cavity and a small number of lightly in- ed fish were removed from the fish market either to a convenient fish-yard or to the Marine Labora- for detailed examination of the flesh. After noting its length, weight, sex and general condition of flesh, each fish was either filleted or cross-sectioned at intervals of from two to three inches along its re length. All cysts appearing on the exposed surfaces of the flesh were then counted, care being n to avoid the duplication of severed cysts in the totals. Observations were next made on the size appearance of the cysts and on their distribution within the flesh. In view of the large numbers of s observed in the course of the investigations it was impossible to examine and identify each cyst vidually. Samples, however, were preserved periodically for identification in the laboratory. These cated quite conclusively that, with few exceptions, the cysts represented the plerocercoid stage of larvae of *Grillotia erinaceus*.

EXAMINATION OF COMMERCIAL CATCHES

One of the main objectives of these investigations was the location of the grounds from which the m-infested fish were originating. For this purpose the port of Aberdeen is particularly suitable since but are landed here from most of the grounds in the North Atlantic where this species is caught, ading the small oceanic banks (see Figure 1). It is proposed to deal with each ground or region vidually.

North Sea

The North Sea, which for the present purpose is regarded as bounded in the north by latit 62°N and in the west by the Shetland-Orkney line, is now but a minor source of halibut in Scot fisheries. The stock consists chiefly of immature and adolescent fish which are caught by great-line north-eastern grounds, chiefly from March to June, and by trawl in the north-western sector throu out the year. Adult fish, mainly large, spent individuals, are occasionally caught by trawl in the la half of the year. Although McIntosh (1892 and 1893) refers to the capture of a few ripe halibut in northern North Sea, neither the Scottish research vessel records since the end of the first Great War the present observations on commercial catches show any clear evidence of the spawning of this spe within the North Sea. Moreover Tåning (1936) is of the opinion that the halibut spawns in waters beyond the greatest depth of the North Sea. It would appear, therefore, that the spent halibut caugh this area are immigrants, possibly for feeding purposes.

TABLE I

Infestation of Body Cavity of Halibut
North Sea

Year	1952	1953	1954	1955	1956	Totals
Months	VIII, XI, XII	V to XI	III to V, VII to IX	III to VI, IX, X	III to VIII	
No. catches examined	42	92	67	35	39	275
No. fish examined	272	766	556	218	304	2,116
By trawl	272	191	11	—	—	474
By great-line	—	575	545	218	304	1,642
No. <3 ft in length	226	534	2	—	—	762
No. infested	—	—	—	—	—	—
No. 3 ft and over	46	232	554	218	304	1,354
No. infested	—	—	—	—	—	—

Table I gives details of North Sea halibut examined during the present investigations.

Although halibut of all sizes from 1½ to 6 feet in length were included in the examination no t of encysted larval cestodes was found in any of the body cavities.

North-West Scotland

This area includes all grounds lying west of Orkney and Shetland to the 250 fathoms contour and extends southwestwards from Flugga in the Shetlands to St. Kilda. Within this region great-li

TABLE II

Infestation of Body Cavity of Halibut
North-West Scotland

Year	1952	1953	1954	1955	1956	Totals
Months	VIII, XII	V to XII	IV, V, VIII, IX	IV, V, VIII to X, XII	III to V, VIII	
No. catches examined	16	131	13	14	7	181
No. fish examined	101	766	1,881	862	260	3,870
By trawl	101	477	—	5	—	583
By great-line	—	289	1,881	857	260	3,287
No. <3 ft in length	59	263	—	—	—	322
No. infested	—	—	—	—	—	—
No. 3 ft and over	42	503	1,881	862	260	3,548
No. infested	2	27	76	9	—	114
%	4·8	5·4	4·1	1·0	0·0	3·
Degree of Infestation — Light	2	27	67	9	—	105
Degree of Infestation — Moderate	—	—	9	—	—	9
Degree of Infestation — Heavy	—	—	—	—	—	—

ıte north and west of the Butt of Lewis mainly beyond the 100 fathoms line, where halibut are ıt in spring and in autumn. Trawling, which is prosecuted throughout the year, though with nal emphasis locally, is largely confined to the shallower water within the 100 fathoms contour. halibut taken by trawl are chiefly immature and adolescent fish approaching their first maturity; arger numbers of adult fish are caught in this area than in the North Sea. Those taken by great- ɔff the Butt of Lewis are predominantly adult fish. Details of the sampling in this area are given in e II.

The results show that a relatively small number of the halibut in the area were infested with the e of *Grillotia erinaceus*. Infestation, which was confined to fish of more than 3 feet in length, was ally light; only nine cases were assessed as moderate and none was placed in the heavy category. proportion of affected fish also varied from year to year and it should be noted that more than ɔf the records, including the nine moderately infested fish, were obtained in 1954 when liners ex- nced a very profitable season off the Butt of Lewis. Over the five years infested fish were caught ch month from April to November, with the exception of July, but 80% of these fish were taken ɔril and May at the height of the great-line fishery in this region. The smallest infested fish in the was 3½ feet long and less than half of the total were under 4 feet in length.

Although it has been convenient for several reasons to combine these rather variable grounds under ıame, the area may be divided into three sub-areas in order to study the incidence of infestation in detail.

A. Grounds west of the Butt of Lewis and southwards along the edge of the deep water to St. Kilda.
B. Grounds from west of the Butt of Lewis northeastwards along the edge of the deep water to Shetland.
C. Shallow grounds fished chiefly by trawlers within the triangle formed by the Butt of Lewis, Flugga and the Pentland Firth.

ting fish of less than 3 feet in length the percentages of infested fish are as follows:

Sub-Area	A	B	C
No. fish examined	336	2,273	679
No. infested	36	70	8
%	10·7	3·1	1·2

This reveals a higher percentage of infested fish in the deeper water fished by liners than in the vely shallow water where trawlers operate. A higher infestation is also evident southwest of the of Lewis than north-east of that point. Of the eight parasitised fish recorded from Sub-area C, five caught by trawl and three by line just inside the 100 fm line. The five trawl-caught halibut were rge adult fish from 4 to 6 feet in length. One was taken in June, three in August and one in Sep- er; thus suggesting that these fish, along with other large, unaffected halibut, taken on the same ıds throughout the summer and autumn, had moved on to the trawling grounds after spawning r in the year in deep water.

ıa Head

Although grounds in the vicinity of Barra Head were at one time regularly fished by Aberdeen ls few liners and no trawlers now visit this area. Fortunately, two great-line catches were landed 40 to 50 miles west of Barra Head, the first in June 1953 and the second in May 1954. Details of xamination of these catches are given in Table III.

The absence of halibut of less than 3 feet indicates that the stock fished by liners off Barra Head is ɔminantly, if not entirely, adult in composition. The results show a marked increase in the numbers ested fish when compared with the north-west coast region as a whole and even when compared the adjoining Butt of Lewis/St. Kilda grounds (Sub-area C). A pronounced rise in the degree of ation, including a number of heavily infested fish, is noticeable in the halibut of this area.

TABLE III

Infestation of Body Cavity of Halibut
Barra Head

Year		1953	1954	Totals
No. fish examined		44	87	131
No. <3 ft in length		—	—	—
No. 3 ft and over		44	87	131
No. infested		16	23	39
%		36·4	26·4	29·8
Degree of Infestation	Light	11	14	25
	Moderate	2	9	11
	Heavy	3	—	3

West Ireland

Although frequently fished by great-liners from Aberdeen in the past, western Irish ground now seldom visited. Occasional exploratory trips are made, primarily in search of halibut, which now become scarce on these grounds, and four catches have been examined during the present inve tions—two in October 1953, one in July 1955 and one in September 1956. The first three were obt north-west of Eagle Island and the fourth on Porcupine Bank.

TABLE IV

Infestation of Body Cavity of Halibut
West Ireland

Year		1953	1955	1956	Totals
No. fish examined		190	55	44	289
No. <3 ft in length		15	—	—	15
No. infested		—	—	—	—
%		—	—	—	—
No. 3 ft and over		175	55	44	274
No. infested		38	15	9	62
%		21·7	27·3	20·5	22·6
Degree of Infestation	Light	36	11	6	53
	Moderate	1	4	3	8
	Heavy	1	—	—	1

Table IV, giving the results, again reveals a high incidence of infestation similar to that obs on the Barra Head grounds. A small number of fish of less than 3 feet were all unaffected so that in tion was again confined to the larger fish. Although the appearance of fish of less than 3 feet ind the possible presence of adolescent fish on these grounds the large size of most of the halibut in the ca clearly shows that the stock off the west of Ireland is mainly adult.

Although no data are available from the Irish Sea, where the halibut stock has been severel pleted, it is interesting to recall that Johnstone first demonstrated the presence of plerocercoid lar *Grillotia* in halibut from this region.

Rockall Bank

This bank, which, unlike the areas so far considered, is isolated from the continental shelf deep water channel, is regularly fished by Aberdeen liners from May to October. Occasionally, f may continue into November or even December but in general bad weather hastens the conclusi operations in this area. No trawled fish is landed at Aberdeen from Rockall Bank.

Although it is known that small numbers of immature and adolescent halibut are found on R Bank, particularly in the vicinity of the rock itself, the size composition of the fish shows that the consists almost exclusively of adult fish. The presence of these large fish on the bank from late spri

autumn also suggests that the bank is a feeding ground where the halibut congregate after spawning he adjacent deep water.

TABLE V

Infestation of Body Cavity of Halibut
Rockall Bank

Year	1952	1953	1954	1955	1956	Totals
Months	VII, VIII, XII	V to XI	V to IX	V to IX	IV to XII	
No. catches examined	8	24	23	12	41	108
No. fish examined	166	1,399	1,597	671	2,823	6,656
By trawl	—	—	—	—	—	—
By great-line	166	1,399	1,597	671	2,823	6,656
No. <3 ft in length	10	9	—	—	—	19
No. infested	—	—	—	—	—	—
No. 3 ft and over	156	1,390	1,597	671	2,823	6,637
No. infested	93	375	303	171	1,046	1,988
%	59·6	27·0	19·0	25·5	37·1	30·0
Degree of Infestation: Light	54	310	254	159	700	1,477
Moderate	29	48	37	12	258	384
Heavy	10	17	12	—	88	127

Table V reveals that infestation is again confined to halibut of 3 feet and over (although few below : size were examined) and that the numbers of fish affected and the degree of infestation are as high n the Barra Head and west Irish grounds. Some of the infested fish were from $3\frac{1}{4}$ to 4 feet in length the majority were over 4 feet; most of the heavily infested specimens were over 4 feet in length.

It will also be observed from Table V that the percentage of infested fish varies from 59·6 in 1952 9·0 in 1954. The high figure for 1952 may be due to a tendency to examine mainly large fish during early stages of the investigation. Nevertheless it was noted throughout that the proportion of infested often varied considerably in individual catches from Rockall Bank. Details of each catch cannot be n here but the variability from month to month over the period 1953 to 1956 is shown in Table Va.

TABLE Va

Monthly Infestation of Halibut over 3 ft in Length
Rockall Bank

	1953			1954			1955			1956		
	No. exam.	No. infest.	%	No. exam.	No. infest.	%	No. exam.	No. infest.	%	No. exam.	No. infest.	%
ril	—	—	—	—	—	—	—	—	—	160	31	19·4
ay	—	—	—	170	40	23·5	116	22	19·0	240	90	37·5
ne	14	5	35·7	656	87	13·3	66	9	13·6	225	82	34·2
ly	429	171	39·9	299	94	31·4	223	62	27·8	444	139	31·3
ıg.	260	38	14·6	263	52	19·8	148	39	26·4	739	372	50·3
pt.	308	76	24·7	209	30	14·4	118	39	33·0	518	149	28·8
ct.	222	47	21·2	—	—	—	—	—	—	341	137	40·2
ov.	166	48	28·9	—	—	—	—	—	—	116	45	38·8
ec.	—	—	—	—	—	—	—	—	—	40	1	2·5

A closer study of the fishing grounds suggested the possibility of this being due to the catches origina- from different localities on the bank but attempts to verify this proved difficult in view of the number ositions fished by most vessels during any single trip. Several catches, however, were found to have n obtained mainly from one or the other of two localities. Seven of these from 100 to 120 miles south- : of Rockall and five from immediately to the north and north-east of the rock gave the following lts.

	No. catches	No. fish examined	No. infested	%
S.W. of Rockall	7	357	203	56·8
N. & N.E. of Rockall	5	232	23	9·9

These figures show that the proportion of infested fish was very high at the southern end of the and relatively low at the northern end. At the former locality fishing depths range from 150 to fathoms with a sea bottom mainly of fine sand whereas at the latter the grounds lie mainly with 150 fathom contour where patches of hard, rocky bottom and strong tides frequently cause loss of While these physical features must be taken into account in seeking an explanation of the differe the numbers of infested fish at the two extremities of the bank it seems probable that biological f are also responsible to some extent. Since it is known that the main halibut stocks invade the rela shallow water of the bank for feeding purposes during the early summer and retire to deep wa preparation for spawning before the end of the year, it may be that the variable proportions of in fish locally on the bank throughout the fishing season are determined by the place of origin of th in the surrounding deep water.

Hatton, George Bligh and Rosemary Banks

These banks, lying from north-west to north-east of Rockall, are only occasionally fished by liners from Aberdeen. With the exception of a small area on Rosemary Bank all known soundi these grounds exceed 200 fathoms. In view of their limited area liners seldom fish them throug complete trip with the result that catches are generally mixed with part catches from neighb banks to the north or from Rockall Bank to the south. However, five catches obtained either enti predominantly from the three banks were examined in May, June, August and November of 1953 i the results set out in Table VI.

TABLE VI

Infestation of Body Cavity of Halibut
Hatton, George Bligh and Rosemary Banks

Year		1953
No. fish examined		502
No. <3 ft in length		—
No. infested		—
No. 3 ft and over		502
No. infested		64
%		12·7
Degree of Infestation	Light	50
	Moderate	12
	Heavy	2

TABLE VIa

Infestation of Halibut According to Size Group
Hatton and George Bligh Banks

Size Group	3 to 3½ ft	3½ to 4½ ft	4½ to 6 ft	Total
No. examined	12	66	38	116
No. infested	—	11	17	28
%	—	17	45	24

All the fish examined were over 3 feet in length thus indicating that the halibut stock on these water banks consists of adult fish. However, the capture by a research vessel of two female fish on mary Bank of just under 3 feet in length, whose reproductive organs showed that they had not yet spa is evidence that at least a small proportion of the halibut population is adolescent.

Table VI shows a much smaller percentage of infested fish compared with Rockall Bank and the previous grounds. Further evidence was obtained in this case of the higher degree of infestation among the large fish. This is demonstrated by the results of detailed measurements made on one particular catch from Hatton and George Bligh Banks in August 1953 (Table VIa).

usy or Outer Bailey Bank

Lousy Bank is known by this name amongst Aberdeen fishermen because of the frequency with which hooked fish are attacked by 'sea lice' or predatory isopods and amphipods such as *Cirolana borealis* and *Tmetonyx cicada*. Lying west of the southern point of Faroe, this bank is greater in extent and shallower than the three banks which have just been considered. It is fished every year from May to September by great-liners from Aberdeen and occasionally also in the last quarter if weather conditions permit. Otter trawled fish is landed from this ground.

The extent of the sampling and the results of the inspection of halibut from Lousy Bank are given in Table VII. This bank differs from Rockall and the other oceanic banks dealt with so far in that it reports a fairly high proportion of fish of less than 3 feet in length. A study of the gonads of these fish, most of which lie within the 2 to 3 feet length range, shows that some of the males and all the females are still in the adolescent state. Nevertheless the bulk of the halibut stock in this area consists of adult fish which appear to visit the bank for feeding purposes after spawning earlier in the year.

TABLE VII

Infestation of Body Cavity of Halibut
Lousy Bank

Year	1952	1953	1954	1955	1956	Totals
Months	VIII, XII	V, VII to XI	V, VII, IX, XI	V to VIII, XI, XII	VI to X	
No. catches examined	2	14	4	6	9	35
No. fish examined	100	1,177	528	384	526	2,715
By trawl	—	—	—	—	—	—
By great-line	100	1,177	528	384	526	2,715
No. <3 ft in length	55	334	—	—	—	389
No. infested	—	2	—	—	—	2
%	—	0·6	—	—	—	0·5
Degree of Infestation: Light	—	2	—	—	—	2
Degree of Infestation: Moderate	—	—	—	—	—	—
Degree of Infestation: Heavy	—	—	—	—	—	—
No. 3 ft and over	45	843	528	384	526	2,326
No. infested	9	132	49	61	179	430
%	20·0	15·7	9·3	15·9	34·0	18·5
Degree of Infestation: Light	8	106	33	52	135	334
Degree of Infestation: Moderate	1	21	14	7	38	81
Degree of Infestation: Heavy	—	5	2	2	6	15

TABLE VIIa

Monthly Infestation of Halibut over 3 ft in Length
Lousy Bank

	1953			1954			1955			1956		
	No. exam.	No. infest.	%	No. exam.	No. infest.	%	No. exam.	No. infest.	%	No. exam.	No. infest.	%
May	15	4	26·7	167	17	10·2	116	9	7·8	—	—	—
June	—	—	—	—	—	—	—	—	—	144	35	24·3
July	16	1	6·3	63	3	4·8	39	9	23·1	116	37	31·9
Aug.	201	29	14·4	—	—	—	100	34	34·0	84	36	42·9
Sept.	91	11	12·1	225	14	6·2	—	—	—	90	32	35·6
Oct.	242	42	17·4	—	—	—	—	—	—	92	39	42·4
Nov.	278	45	16·2	73	15	20·5	48	4	8·3	—	—	—
Dec.	—	—	—	—	—	—	19	3	15·8	—	—	—

In addition to the higher proportion of small fish in the catches Table VII shows for the first time, the grounds considered so far, a slight infestation in fish of less than 3 feet. In the larger size category the percentage of infested fish is again lower than on Rockall Bank.

On this bank the annual percentages of infested fish again vary considerably—from 9·3 in 19 34·0 in 1956. Similarly the monthly figures range from 4·8 in July 1954 to 42·9 in August 195 Table VIIa). Since the area of Lousy Bank is too small and the nature of the sea bottom too unifo permit an explanation on the basis of indigenous local stocks, the explanation of the monthly and y variations would again appear to depend on the nature of the deep water habitats.

Bill Bailey's Bank

This small and comparatively shallow bank lying to the eastward of Lousy Bank is visit Aberdeen liners every summer. Fishing is mainly carried on in June although even in this mon indeed at any other time, strong tides and heavy seas frequently curtail lining in this area.

On each of the grounds hitherto considered in this investigation, with the exception of the Sea and the shallower parts north-west of Scotland, the halibut population fished by means of g lines has consisted predominantly of adult fish. On Bill Bailey's Bank, however, most of the ha are from 2 to 3 feet in length. Although during these investigations none was actually found to b than 2 feet there is no reason why smaller, immature fish should not be present on this bank. the general size of the halibut caught by great-liners and from the appearance of the gonads, it is cluded that the stock is largely adolescent in character.

Encysted cestode larvae were again found in the body cavity of fish of less than 3 feet in le On this occasion the numbers affected were rather higher than on Lousy Bank but as hitherto the he infestation was again found in the larger fish (Table VIII).

TABLE VIII

Infestation of Body Cavity of Halibut
Bill Bailey's Bank

Year	1952	1953	1954	1955	1956	Totals
Months	VIII	V to VII	VI	VI	IV to IX	
No. catches examined	2	12	1	4	34	53
No. fish examined	60	619	76	116	929	1,800
By trawl	—	—	—	—	—	—
By great-line	60	619	76	116	929	1,800
No. <3 ft in length	30	396	—	—	—	426
No. infested	1	10	—	—	—	11
%	3·3	2·5	—	—	—	2·6
Degree of Infestation: Light	1	10	—	—	—	11
Degree of Infestation: Moderate	—	—	—	—	—	—
Degree of Infestation: Heavy	—	—	—	—	—	—
No. 3 ft and over	30	223	76	116	929	1,374
No. infested	7	35	6	10	203	261
%	23·3	15·7	7·9	8·6	21·9	19·0
Degree of Infestation: Light	6	29	5	9	132	181
Degree of Infestation: Moderate	—	3	1	1	62	67
Degree of Infestation: Heavy	1	3	—	—	9	13

TABLE VIIIa

Monthly Infestation of Halibut over 3 ft in Length in 1956
Bill Bailey's Bank

Month	No. catches	No. fish examined	Degree of infestation L.	M.	H.	Total infested	%
April	5	114	4	—	—	4	3·5
May	9	210	12	—	—	12	5·7
June	5	112	10	—	—	10	8·9
July	5	157	22	20	1	43	27·4
Aug.	5	236	76	37	7	120	50·8
Sept.	5	100	8	5	1	14	14·0

Good halibut fishing was experienced on Bill Bailey's Bank in 1956 and as a result the numb fish examined, over 3 feet in length, was greater than the total for the other four years. Table V

ng the monthly figures for 1956, again reveals the variable proportions of affected fish as observed ɔther banks and, in addition, indicates an invasion of the bank in July and August by shoals which ude a much higher proportion of infested fish than those fished earlier in the year. The results obtained September reveal an equally sudden decline in the numbers of infested halibut which would appear ndicate their withdrawal from the bank.

ROE BANK

Faroe Bank, lying between Bill Bailey's Bank and the southern point of the Faroe Islands, covers reater fishable area than any of the oceanic banks except Rockall. On an average it is also rather lower than any of the other banks and accordingly more suitable for trawling although few Aberdeen vlers operate on it. On the other hand because of its relative proximity to the shelter of the Faroes, rdeen liners work on Faroe Bank almost throughout the entire year, although their maximum effort nfined to the period May to September.

The average size of the halibut taken by liners on Faroe Bank is, as on Bill Bailey's Bank, much iler than on the other oceanic banks. While the majority of the fish measured from 2 to 3 feet some hes from the deeper water on the edge of the bank include a higher proportion of large fish than one s from Bill Bailey's Bank. Although great-line catches indicate a preponderance of adolescent fish in halibut stock on Faroe Bank, trawl catches by commercial and research vessels reveal the presence of tantial quantities of immature fish of 'chicken' size. The capture by a research vessel of small halibut ging as low as 14 cm also suggests that Faroe Bank is a nursery ground for this species.

TABLE IX

Infestation of Body Cavity of Halibut
Faroe Bank

Year	1952	1953	1954	1955	1956	Totals
Months	VII, XII	V to XI	III, IV, VI to IX	IV to XII	IV to XII	
No. catches examined	2	37	26	18	56	139
No. fish examined	61	1,784	856	675	1,085	4,461
By trawl	—	—	—	4	—	4
By great-line	61	1,784	856	671	1,085	4,457
No. <3 ft in length	33	786	120	—	—	939
No. infested	—	5	—	—	—	5
%	—	0·6	—	—	—	0·5
Degree of Infestation — Light	—	5	—	—	—	5
Degree of Infestation — Moderate	—	—	—	—	—	—
Degree of Infestation — Heavy	—	—	—	—	—	—
No. 3 ft and over	28	998	736	675	1,085	3,522
No. infested	1	75	21	24	54	175
%	3·6	7·5	2·9	3·6	5·0	5·0
Degree of Infestation — Light	1	55	16	20	45	137
Degree of Infestation — Moderate	—	15	4	4	9	32
Degree of Infestation — Heavy	—	5	1	—	—	6

TABLE IXA

Monthly Infestation of Halibut over 3 ft in Length
Faroe Bank

ear	1953			1954			1955			1956		
Month	No. fish	No. infest.	%	No. fish	No. infest.	%	No. fish	No. infest.	%	No. fish	No. infest.	%
lar.	—	—	—	119	—	—	—	—	—	—	—	—
pr.	—	—	—	79	—	—	124	3	2·4	59	1	1·7
lay	80	7	8·8	—	—	—	85	2	2·4	230	3	1·3
ne	129	28	21·7	158	5	3·2	402	18	4·5	378	12	3·2
ly	255	23	9·0	195	6	3·1	186	9	4·8	280	27	9·6
ug.	325	12	3·7	164	10	6·1	27	1	3·7	40	9	22·5
pt.	252	6	2·4	21	—	—	—	—	—	29	—	—
ct.	25	—	—	—	—	—	—	—	—	23	2	8·7

Table IX shows that halibut of less than 3 feet on Faroe Bank, like those on Lousy Bank an Bailey's Bank, are affected to a slight extent by cestode larvae. Although the larger fish are again heavily infested than the smaller individuals, the percentage so affected is much lower than on a the other oceanic banks. As may be expected the annual variation in the proportion of infested h is much less than on the banks considered hitherto but a marked difference in the monthly percen is still perceptible in certain years. This is demonstrated in Table IXa in which it is also interest note some evidence of a sudden incursion of infested fish in July and August 1956 similar to that al observed on Bill Bailey's Bank.

South and West Faroe

At first it was intended to regard the grounds round the Faroes as one area but the discover small number of worm-infested fish on the more southerly grounds prompted the recognition o areas separated by a line joining points a little to the north of the most northerly positions on bot east and the west coasts from which infested fish were recorded. This demaracation line runs fro western point of Myggenaes north-west to the edge of the plateau and south-east to the southe of Sando and thence eastwards to the northern edge of Sando Bank.

Grounds to the south of this line are fished throughout the year by great-liners from Aber Trawlers from the port although occasionally working the shallower water to the west and so Sydero are generally more active on northern Faroese grounds so that few trawl-caught halibut examined from the southern grounds as Table X shows.

TABLE X

Infestation of Body Cavity of Halibut
South and West Faroe

Year	1952	1953	1954	1955	1956	Tot
Months	VIII, XI, XII	VI to XII	II, III, VI to IX	I to III, V to XII	II to IV, VI to XII	
No. catches examined	8	28	13	30	35	11
No. fish examined	170	1,202	458	1,107	475	3
By trawl	24	11	—	—	—	
By great-line	146	1,191	458	1,107	475	3,37
No. <3 ft in length	86	303	65	—	—	45
No. infested	—	1	—	—	—	
%	—	0·3	—	—	—	
Degree of Infestation: Light	—	—	—	—	—	
Degree of Infestation: Moderate	—	1	—	—	—	
Degree of Infestation: Heavy	—	—	—	—	—	
No. 3 ft and over	84	899	393	1,107	475	2,95
No. infested	8	52	8	14	25	10
%	9·5	5·8	2·0	1·2	5·3	
Degree of Infestation: Light	7	47	8	14	23	9
Degree of Infestation: Moderate	1	5	—	—	2	
Degree of Infestation: Heavy	—	—	—	—	—	

The halibut examined from southern and western Faroese grounds include all sizes from 1 f 6 feet in length. Measurements, together with a study of the condition of the reproductive organs onstrate a mixed population of immature, adolescent and adult fish on these grounds. Within t fathoms contour line, on grounds fished mainly by trawlers, immature fish are most numerous the deeper waters fished by great-liners the stocks consist mainly of adolescent and adult fish.

Table X shows a further decline in the numbers of infested fish both above and below 3 f length. In the smaller category only one fish was found to be infested out of 454 examined. This spec however, was unique in being moderately infested within the body cavity and thus the only fish size throughout the investigations showing a degree of infestation heavier than 'light'. A decline i degree of infestation in the larger sizes is reflected in the increased proportion of fish in the lightly in category, the reduced numbers of those only moderately infested and the complete absence of h infested specimens.

TH AND EAST FAROE

This area includes all Faroese fishing grounds north of the Myggenaes/Sandø Bank line. Aberdeen lers operate in this area throughout the year but on the whole Scottish great-liners are not active hese grounds. Representative samples of line-caught fish have been obtained by including some ɔut caught by Faroese liners.

The halibut examined from this area included all sizes from 1 foot to 6 feet although the average is much smaller than in any of the areas considered so far. This is due to the large quantities of ature or 'chicken' halibut landed by trawlers from this region which is one of the most important ɔut nursery grounds in the North Atlantic.

Although the stock consists predominantly of immature fish of less than 4 years of age, appreciable ıtities of adolescent and adult fish are also present, particularly in the deeper water surrounding the ling grounds.

No trace of worm infestation in the body cavity was found in any of the fish examined (Table XI).

TABLE XI

Infestation of Body Cavity of Halibut
North and East Faroe

Year	1952	1953	1954	1955	1956	Totals
Months	VIII, XII	V to XII	VI to IX	I, III, VI to XI	I to IV, VI to VIII	
No. catches examined	37	77	13	18	14	159
No. fish examined	140	562	687	828	123	2,340
By trawl	140	191	30	3	8	372
By great-line	—	371	657	825	115	1,968
No. <3 ft in length	62	152	6	—	—	220
No. infested	—	—	—	—	—	—
No. 3 ft and over	78	410	681	828	123	2,120
No. infested	—	—	—	—	—	—

TH ICELAND

For the purpose of this paper, South Iceland is regarded as stretching from the Beru Deep, off south-Iceland, to south of Reykjanes. The halibut population in this area is composed of immature, adoles- and adult fish. As in previous mixed populations, the smaller and younger fish are exploited chiefly awlers and the larger and older fish by liners.

TABLE XII

Infestation of Body Cavity of Halibut
South Iceland

Year	1952	1953	1954	1955	1956	Totals
Months	VIII, XI, XII	V to XII	I to IX	III, VII, IX to XI	IV, VI to X	
No. catches examined	9	30	7	6	11	63
No. fish examined	265	1,114	185	107	52	1,723
By trawl	44	81	—	—	—	125
By great-line	221	1,033	185	107	52	1,598
No. <3 ft in length	106	266	—	—	—	372
No. infested	—	—	—	—	—	—
No. 3 ft and over	159	848	185	107	52	1,351
No. infested	—	1	—	—	—	1
%	—	0·1	—	—	—	0·1
Degree of Infestation: Light	—	1	—	—	—	1

The halibut examined from these grounds ranged from 1 foot to nearly 7 feet in length and only ish was found to be parasitised by larvae of *Grillotia erinaceus* (Table XII). This fish, the largest in a of 96 halibut ranging from less than 3 feet to nearly 6 feet in length, was caught by great-line in ɔon Deeps early in September 1953. The body cavity was only lightly affected.

West Iceland

This area comprises all fishing grounds from west of Reykjanes northwards to the Vikurall
Aberdeen trawlers seldom visit this area but great-line vessels operate regularly throughout the y
the deep water beyond the 100 fathoms line. The fish examined from this area, although inclu
small number of less than 3 feet, were mainly of a large size, thus indicating conclusively that the
exploited by great-liners are almost exclusively adult in composition. This is further confirmed
fact that spawning fish are occasionally caught in this region from December to May. In Decembe
for example the ovaries of large numbers of big halibut were fully developed with glassy eggs. O
same occasion large halibut roes from west Iceland grounds were offered for sale separately at the
deen fish market. In one sample of 75 fish only the four smallest fish (each about 3 feet long) were re
as not being at the ripe stage. Most of the fish in this case were females, a feature which characte
succession of halibut catches from West Icelandic grounds in December 1952. It should be stated ho
that no similar concentration of halibut was located on these grounds in December of any of th
years which followed.

TABLE XIII

Infestation of Body Cavity of Halibut
West Iceland

Year	1952	1953	1954	1955	1956	Totals
Months	VIII, XII	V to XI	I to IX	I to XII	I, IV, V, VII to XII	
No. catches examined	9	42	22	31	18	122
No. fish examined	655	2,722	535	259	108	4,279
By trawl	—	—	—	—	—	—
By great-line	655	2,722	535	259	108	4,279
No. <3 ft in length	15	42	—	—	—	57
No. infested	—	—	—	—	—	—
No. 3 ft and over	640	2,680	535	259	108	4,222
No. infested	—	—	—	—	—	—

Table XIII gives details of the fish inspected on Aberdeen fish market. Although more th
thousand halibut were examined from this region, no trace of *Grillotia* larvae was found in the fi

East Greenland

East Greenland grounds, extending from Cape Dan to Griffenfeldts Island, are fished eve
by great-lines from Aberdeen, from May to August, depending on the location of the ice. These g
are quite unsuitable for trawling. The general size of the halibut landed by the liners, during th
under review, was noticeably smaller than that of the fish caught by the same method on the Ic
side of the Denmark Strait. This suggests that the East Greenland stock includes a larger propor
smaller and probably younger fish.

TABLE XIV

Infestation of Body Cavity of Halibut
East Greenland

Year	1952	1953	1954	1955	1956	Totals
Months	VIII	VI to VIII	V	VII, VIII	VI	
No. catches examined	2	6	1	2	1	12
No. fish examined	75	659	15	21	6	776
No. <3 ft in length	20	69	—	—	—	89
No. infested	—	—	—	—	—	—
No. 3 ft and over	55	590	15	21	6	687
No. infested	—	—	—	—	—	—

Table XIV shows that no trace of larvae of *Grillotia erinaceus* was found in any of the fish fr
region.

Fig. 2 Body cavity of halibut showing light infestation by encysted larvae of *Grillotia erinaceus*.

Fig. 3 Body cavity of halibut showing heavy infestation by encysted larvae of *Grillotia erinaceus*. (*Photos*: R. Priestley).

Fig. 4 Cross sections of halibut showing infestation of the flesh by larvae of *Grillotia erinaceus*. Note concentration of cysts in ventral (lower in picture) half of the fish. (*Photo* R. Priestley)

Fig. 5 Section of oesophagus of halibut showing heavy local concentration of encysted cestode larvae close to blood vessels. (*Photo*: D. D. Seaton).

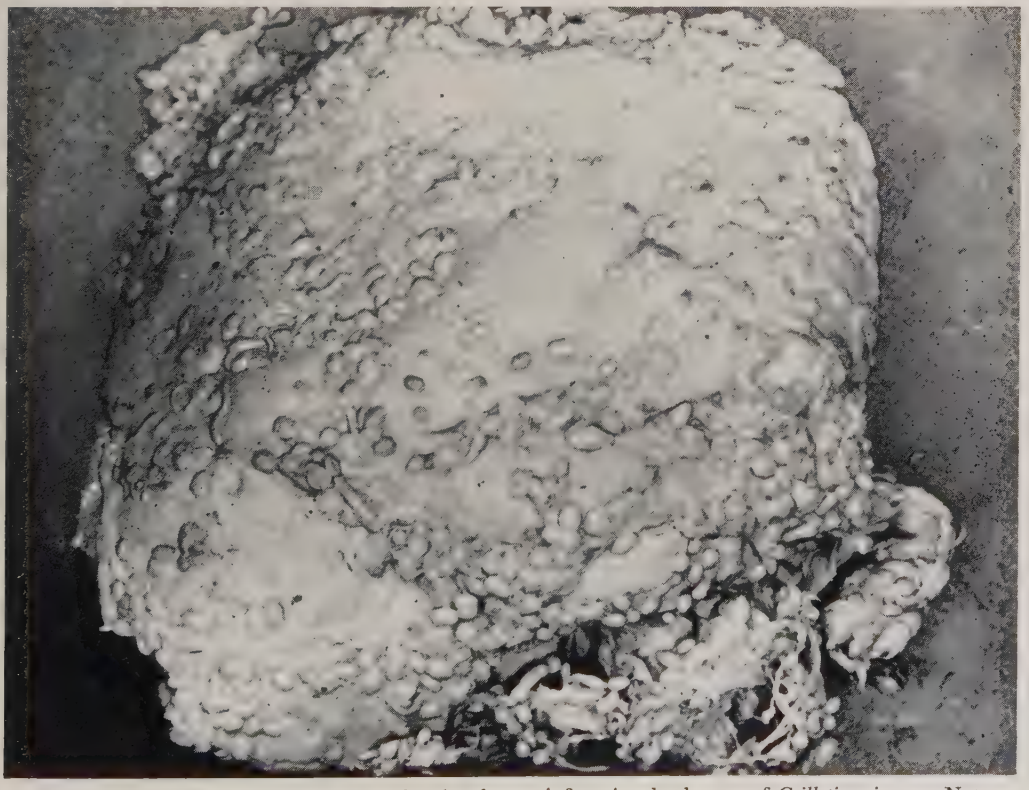

Fig. 6 Part of liver of large halibut showing heavy infestation by larvae of *Grillotia erinaceus*. Note also encysted larval nematodes. (*Photo*: R. Priestley).

Greenland

This area is rarely visited by fishing vessels from Aberdeen. Great-line catches, however, were d from Little Hellefiske Bank and southwards in August 1952 and July 1953. Twenty-five halibut also examined from a catch by an English trawler which had fished off Cape Christian in November

The results of the examination of these fish, which in general size resembled those from East Green- again reveal the complete absence of infestation by *Grillotia* (Table XV).

TABLE XV

Infestation of Body Cavity of Halibut
West Greenland

Year	1952	1953	Totals
No. fish examined	75	260	335
No. <3 ft in length	40	—	40
No. infested	—	—	—
No. 3 ft and over	35	260	295
No. infested	—	—	—

vegian Coast

berdeen vessels rarely fish off the Norwegian coast. Thirteen halibut trawled off Andanes by n vessels and twenty-six line-caught fish, from grounds between Andanes and Bergen, were examined February to May 1955. None of the thirty-nine fish, which included five of less than 3 feet, was to be infested.

nts Sea

n recent years no Aberdeen vessel has fished in the Barents Sea. Catches are, however, occasionally d at the port by English or foreign vessels and from one of these three halibut of less than 3 feet examined in December 1952. No cestode larvae were observed in these fish.

DISCUSSIONS OF RESULTS OF MARKET INVESTIGATIONS

These observations on commercial catches from which, in all, 35,447 halibut were examined, are arised in Table XVI. Plerocercoid larvae of *Grillotia erinaceus* are shown to be parasitic on the of the body cavity of halibut on a number of grounds in the North Atlantic. No trace of this parasite, ver, was found in fish from the following regions—the North Sea, North and East Faroe, Iceland, t for one isolated record, and Greenland. Although few, or in some cases no fish, have been examined he Norwegian coast, Bear Island, Spitzbergen, the Barents Sea, North Iceland, Newfoundland and American grounds, it seems probable that larvae of *Grillotia* are not present in the peritoneal lining body cavity or in the flesh of halibut in these regions. This view is based partly on the rather limited s referred to above but mainly on replies to personal enquiries addressed to fishery scientists in la and Norway and to English colleagues serving on the research vessel *Ernest Holt* in the Barents nd in the Spitzbergen and Bear Island regions. In each case it was stated that larval cestodes have en recognised in halibut from the particular region or regions with which the writers were concerned. theless, bearing in mind that both larval and adult forms of *Grillotia erinaceus* have been identified er species of fish from the American coast (Linton 1891) and from the Norwegian coast (Dollfus the possibility of the larval parasite being present on the gut, for example, of halibut from these is cannot be disregarded. But as there is no evidence of the occurrence of the parasite in the flesh nomic problem arises.

t is apparent, therefore, that the main concentrations of halibut on northern grounds are free from s infestation by this parasite and that the problem mainly affects the numerous small localities and lying to the west and north-west of the British Isles.

TABLE XVI

Degree of infestation and distribution of *Grillotia erinaceus* in halibut in the North Atlantic

Region	Total no. fish exam.	<3 ft in length: No. Exam.	No. infested	%	Degree of infestation L.	M.	H.	3 ft and over: No. exam.	No. infested	%	Degree of infestation L.	M.	H.
North Sea	2,116	762	—	—	—	—	—	1,354	—	—	—	—	—
N.W. Scotland	3,870	322	—	—	—	—	—	3,548	114	3·2	105	9	—
Barra Head	131	—	—	—	—	—	—	131	39	29·8	25	11	3
West Ireland	289	15	—	—	—	—	—	274	62	22·6	53	8	1
Rockall Bank	6,656	19	—	—	—	—	—	6,637	1,988	30·0	1,477	384	127
Hatton, George Bligh, Rosemary Banks	502	—	—	—	—	—	—	502	64	12·7	50	12	2
Lousy Bank	2,715	389	2	0·5	2	—	—	2,326	430	18·5	334	81	15
Bill Bailey's Bank	1,800	426	11	2·6	11	—	—	1,374	261	19·0	181	67	13
Faroe Bank	4,461	939	5	0·5	5	—	—	3,522	175	5·0	137	32	6
South and West Faroe	3,412	454	1	0·2	—	1	—	2,958	107	3·6	99	8	—
North and East Faroe	2,340	220	—	—	—	—	—	2,120	—	—	—	—	—
South Iceland	1,723	372	—	—	—	—	—	1,351	1	0·1	1	—	—
West Iceland	4,279	57	—	—	—	—	—	4,222	—	—	—	—	—
East Greenland	776	89	—	—	—	—	—	687	—	—	—	—	—
West Greenland	335	40	—	—	—	—	—	295	—	—	—	—	—
Norwegian Coast	39	5	—	—	—	—	—	34	—	—	—	—	—
Barents Sea	3	3	—	—	—	—	—	—	—	—	—	—	—

It is also clear from a study of Table XVI that infestation is very slight in halibut of less than 3 in length. Out of 4,112 fish of this size category examined only nineteen, or less than 1% were parasi and of these all but one were lightly affected. Furthermore, the nineteen records were all obtained fish in the 2 to 3 feet size range. This fact and the absence of cysts from the 'chicken' halibut ind that the initial infestation does not occur during the immature period of the halibut's life on the nu grounds but at some later stage of its adolescent or adult life. Table XVI clearly demonstrates the dominance of the infestation in fish of 3 feet and over. From general observation throughout the m investigations it has been noted that on an average the proportion of infested fish increases with the of the fish. Unfortunately circumstances did not permit taking enough measurements of large fis demonstrate this point more conclusively but Table VIa, dealing with one particular catch, is f typical and perhaps sufficiently conclusive. It would appear, therefore, that although infestatio adolescents by the larvae of *Grillotia erinaceus* may occasionally take place it is confined mainly to a or mature halibut and is accumulative from year to year.

Tables I to XVI also show that the percentages of infested fish vary from ground to ground, f year to year and from month to month. The heaviest infestation occurs in the Barra Head, Irish C and Rockall Bank grounds where from 30 to 21% of the fish are affected. Northwards from these ce and separated from them and from each other by deep water channels lie Hatton, George Bligh, R mary, Lousy and Bill Bailey's Banks, on which infestation is confined to between 20 and 11% of larger fish. The Butt of Lewis to St. Kilda section of the north-west Scotland area (Sub-area C) may be included with this group. The proportion of affected fish again declines to from 10 to 1% off no west Scotland, on Faroe Bank and on south and west Faroese grounds. The single record of a lig infested fish from south Iceland places this region in a group by itself with an infestation of less than

In order to compare the degrees of infestation on the different grounds the numbers represen the lightly, moderately and heavily infested fish of 3 feet and over have been converted to percent in Table XVII.

This shows remarkably little variation in the degree of infestation on most of the affected grou Heavily infested fish were found in relatively the same proportions on all grounds except those of no west Scotland, south and west Faroe and south Iceland, where no heavily infested fish were encount and where the proportions of moderately affected fish were low. These results appear to emphasise marginal nature of the infestation on north-west Scottish, Faroese and south Icelandic grounds.

TABLE XVII

Degree of Infestation

Region	Total Infested	% of fish in each category Light	Moderate	Heavy
N.W. Scotland	114	92	8	—
Barra Head	39	64	28	8
W. Ireland	62	85	13	2
Rockall Bank	1,988	74	19	7
Hatton, George Bligh, Rosemary Banks	64	78	19	3
Lousy Bank	430	78	19	3
Bill Bailey's Bank	261	69	26	5
Faroe Bank	175	78	18	4
South and West Faroe	107	93	7	—
South Iceland	1	100	—	—

OCCURRENCE OF THE LARVAE IN THE FLESH OF THE HALIBUT

As already indicated on page 5 all halibut showing moderate or heavy infestation of the body y and a small number of lightly affected fish were removed from the fish market for a more detailed tigation of the numbers and distribution of the parasites within the flesh of the fish. With a view to ble salvage of unaffected parts many of the fish were filleted but not skinned. Counts were then of all cysts observed on or near the exposed surface of the fillets. Considerable variation was ob- d in the size and general appearance of the cysts throughout the fish. The smallest individuals, with meter of about one millimetre, were mainly located in the rather inferior flesh of the 'flaps' sur- ding the body cavity, while large, apparently well-nourished, larvae of ten millimetres or more the major axis were generally grouped on the wall of the alimentary canal or in the muscles. A ble proportion of the cysts consisted of the small degenerate type described by Johnstone (1912). latter were usually identified by their yellowish colour and, on closer examination, by their gritty e due to calcification of the dead tissue.

During 1953 and 1954 forty-seven fish were dealt with in this way the details of which are sum- ed in Table XVIII.

TABLE XVIII

Infestation of the flesh of halibut

Description of fillet	Dorsal Lower	Dorsal Upper	Ventral Lower	Ventral Upper
Total number of cysts in 47 fish	130	86	691	791
Range in number per fillet	0-14	0-10	1-52	1-103
Average number per fillet	2·8	1·8	14·7	16·8

The dorsal fillets ranged in length from about 2 to $3\frac{1}{2}$ feet and in weight from about 4 to 17 pounds. ventral fillets naturally measured and weighed rather less than the dorsals. The counts show quite usively that the dorsal fillets were much less affected by parasites than the ventrals. This was found quite pronounced in every fish examined and would appear to be invariable. It may also be ob- d from Table XVIII that the average number of worm larvae for each of the four fillets is relatively ndicating that there were really few fish with a high degree of infestation.

A rather less accurate count of cysts was carried out by the Fish Inspectors on the fillets of twenty- of the most heavily infested halibut during 1955. The numbers of cysts again showed that the dorsal were in every case much less affected than the ventrals. The average numbers for the dorsal fillets

in 1955 also agree with the corresponding figures for 1953-54 in showing the upper fillet to be g
less affected than the lower. No obvious difference of this nature was found in the two ventral f

The remaining halibut detained for further examination during 1953 and 1954 were cross-
sections of from 2 to 3 inches thick. This treatment was adopted to obtain another count of cy
check on the previous method and to study the distribution of the parasite within the flesh from
angle, while simulating the general method of cutting up when retailing this species. In this
counts were made of cysts exposed on both surfaces of each cut, care again being taken to avoid c
severed cysts twice. Distinction was again drawn between the dorsal and ventral halves of the
and, in order to overcome the difficulty created by the varying size of the sections from behind t
backwards to the caudal peduncle, resulting from differences in the size of the fish, the sections ha
arranged roughly in three groups according to their position in the body of the halibut. The
obtained on the twenty fish thus examined are set out in Table XIX.

TABLE XIX

Infestation of the flesh of halibut as demonstrated by cross-sections

		Region of body cavity 3 cuts per fish	Region posterior to body cavity 3 to 11 cuts per fish	Tail region 2 to 3 cuts per
Dorsal Half .	Range in average no. of cysts per cut . .	0·0 to 5·7	0·1 to 5·3	0·0 to 4·7
	Average per cut for 20 fish examined .	0·9	1·8	0·8
Ventral Half .	Range in average no. of cysts per cut . .	2·7 to 67·7	1·7 to 39·5	0·0 to 20·0
	Average per cut for 20 fish examined .	17·2	10·9	4·4

The numbers of cysts exposed by this method were naturally greater than those obtained fr
face counts on the fillets since the area of muscle tissue involved was so much greater. If, however,
areas of flesh are compared the figures derived from the two methods are remarkably alike. Tab
again stresses the heavier concentration of cysts in the ventral region of the fish (Figure 4) a
appears to indicate variable concentrations lengthwise. In order to verify this point the average
table have been transformed to represent the ratio in which cysts are present per unit of surface
the different regions of the body. The figures obtained in this way are as follows:

	Region of Body Cavity	Region Posterior to Body Cavity	Tail Region
Dorsal Half .	1·0	2·5	4·0
Ventral Half .	27·0	15·5	22·0

This reaffirms the heavier infestation of the ventral half of the fish and also reveals in this
decline in the degree of infestation posteriorly which is followed by an increase towards the caudal
In the dorsal side, on the other hand, infestation is least immediately above the body cavity while
but gradual increase occurs towards the tail.

These investigations show quite conclusively that infestation by cestode larvae varies consi
throughout the flesh of halibut. In the majority of the dorsal fillets infestation was either absent
slight; on the other hand, although some of the ventral fillets were also slightly affected, most o
were infested to such an extent as to render them unfit for human food on the grounds of their un
appearance. The flesh of about 20% of the fish with moderate or heavy infestation of the body
was regarded as marketable while that of the remaining 80% was considered either partly or com
unsuitable for human consumption.

BIOLOGICAL NOTES ON THE MODERATELY AND HEAVILY INFESTED HALIBUT

During the examination of the more heavily infested halibut, subsequent to their detention on the market, notes were made on the individual fish as circumstances permitted. All the fish examined caught by great-line and specimens were received from each of the affected grounds. Table XX erates the fish detained monthly from 1953 onwards.

TABLE XX

Numbers of halibut detained during market inspection

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Totals
1953	—	—	—	—	?	?	6	16	12	12	10	—	56+
1954	—	1	—	3	28	17	21	9	8	—	—	—	87
1955	—	—	—	—	4	5	8	4	2	—	—	1	24
1956	—	—	—	3	5	18	19	43	12	14	2	—	116

These results show that the more heavily infested fish and also the lightly affected occur in the catches and, with few exceptions, are caught from April to November. Variations in the numbers g this period are due to differences in the incidence of the fishery, which may be affected by the ıce or absence of shoals at a particular time or by bad weather.

ıccurate measurements were obtained of the length of sixty-five halibut during the first two years. ranged from 3 ft 4 in. (101·6 cm) to 5 ft 9 in. (175·3 cm) in length with an average of 4 ft $3\frac{3}{4}$ in. ł cm). Otoliths were procured from fifty-five of these fish but, as is not infrequently experienced with oliths of the older age groups of other species, some difficulty was encountered in the interpretation annual rings. This is due to the closeness of the later winter rings and to a subsidiary zoning effect outer half of the otolith which probably results from the nature of the bone growth. Nevertheless nalysis revealed the halibut to be from eight to eighteen years of age. Thirty-one fish were from 0 years of age, sixteen from 11 to 13 and eight from 14 to 18. The sex organs were left in twenty- fish after gutting, nine of which were males, average length 3 ft $11\frac{2}{5}$ in. (120·4 cm), and eighteen es, average length 4 ft 8 in. (142·2 cm). The condition of the reproductive organs showed quite y that all the fish had spawned although in the majority of those caught towards the end of the ınd in the single fish caught in February recovery was well advanced.

The gutted weights of one hundred and twenty-seven fish were ascertained during 1953 and 1954. veights ranged from $1\frac{3}{4}$ stones (11·1 kg) to $8\frac{1}{4}$ stones (52·4 kg) with an average of $4\frac{1}{4}$ stones (27·0 kg). 55 and 1956 the gutted weights of five hundred and sixteen infested halibut, including many lightly ed fish, were found to range from $1\frac{1}{4}$ stones (7·9 kg) to 10 stones (63·5 kg) with an average of $3\frac{3}{4}$ stones kg).

The general condition of these fish varied considerably. Several were emaciated but on the other the flesh of the most severely infested specimen, in which 935 cysts were exposed by filleting and by sectioning the fillets, appeared to be in good condition, and others seemed to be in prime condition. ugh the poor state of some fish certainly appeared to be due to heavy worm infestation this cannot garded as conclusive since the condition of many of them may have resulted from the effects of spawning.

OCCURRENCE OF THE LARVAE THROUGHOUT THE BODY OF THE HALIBUT

n general the degree of infestation in the peritoneum of the body cavity was slightly heavier than flesh—a feature which naturally created confidence in the method of inspection of the body cavity ɔractical means of recognising possible infestation of the flesh on the market floor. Nevertheless,

doubts still remained regarding halibut with a slight infestation of the body cavity and indeed a
regards fish showing no obvious sign of infestation. A small number of lightly infested fish were exa
and some of them were found to be lightly affected in the flesh. Large numbers of halibut, however
light infestation of the cavity, or with no trace of cysts whatsoever, which passed through the m
at the time of these investigations, produced no subsequent reaction by retailers or by food inspe
It was concluded that the flesh of these fish was either not affected by these parasites in any way o
only to such a minor extent as to be of no significance to the trade.

Pursuing this matter further in order to test the reliability of the inspection methods, seventy
halibut, caught on great-lines by the research vessel *Scotia* were examined for the presence of G
larvae from 1953 to 1956. Sixty-five of these fish were caught on affected grounds including th
of Lewis and St. Kilda areas, Rockall, Rosemary, Lousy and Faroe Banks while the remaining th
fish were taken on west Icelandic grounds. Twenty-nine of the sixty-five fish in the first group r
from $1\frac{1}{2}$ to 3 feet in length and thirty-six from 3 feet to 6 feet 4 inches. Twelve of the fish in the s
category were greater than 2 feet 9 inches. With few exceptions most of the halibut in the large
group were adult fish. The examination of the halibut on the research vessel was carried out in as tho
a manner as conditions at sea permitted and a search was made throughout all tissues for the pr
of cysts. This revealed that the larvae of *Grillotia* may occur in every organ or tissue in the body
halibut from the snout to the base of the fin rays of the caudal fin. Cysts were not infrequently fou
the bone cavities of the head and in some cases even within the cranium. Table XXI gives the nu
of fish affected in the three main centres of infestation in the body of the halibut and Table XX
degree of infestation in these centres.

TABLE XXI

General infestation of halibut caught by research vessel

	<3 feet	%	3 feet and over
Number of fish examined	29	—	36
Number free from infestation	22	76	3
Number infested	7	24	33
Number with infestation of stomach, gut, liver and mesenteries	7	24	33
Number with infestation of body cavity peritoneum	4	14	22
Number with infestation of the flesh	3	10	24

TABLE XXII

Degree of infestation of halibut caught by research vessel

	Stomach, Gut, Liver, Mesenteries				Peritoneum of Body Cavity				Flesh			
	H.	M.	L.	V.L.	H.	M.	L.	V.L.	H.	M.	L.	V.L.
No. <3 ft	1	—	1	5	—	—	1	3	—	—	1	2
Percent	14	—	14	72	—	—	25	75	—	—	33	67
No. 3 ft and over	7	12	9	5	—	7	5	10	1	1	10	12
Percent	21	37	27	15	—	32	23	45	4	4	42	50

Key: H=Heavy M=Moderate L=Light VL=Very Light

Tables XXI and XXII show that the heaviest infestation occurs on the liver and on the alime
canal and its associated mesenteric tissues. Although the entire gut may be affected (Figure 5) the
are generally most densely concentrated on the outer wall of the stomach, on the surface of the
(Figure 6) and in the mesenteries of the stomach, as already noted by Dollfus (1942). The kidney
ovary and the testis are also affected but not to the same degree. Another feature of this infestat
the location of the cysts immediately below the peritoneum or the surface layer of the various or
Despite the frequent occurrence of cysts deep within the muscle tissues their presence within the t
of the liver, kidney, ovary or testis is rare.

Table XXI also shows that in both size categories greater proportions of the halibut are infested are indicated from inspection of the body cavity of fish caught by commercial vessels. It should be nasised, however, that more detailed observations were possible on the research vessel and that the ds under the 'very light' category in Table XXII not infrequently represent the presence of a single If some of the 'very light' records were disregarded the percentages of infested fish would then ar reasonably close to those derived from commercial sources. Furthermore, the relatively high ation values for fish of less than three feet are scarcely comparable with the corresponding figure for caught commercially since the research vessel catches included a higher proportion of fish of just r three feet in length, i.e. 2 feet 9 inches to 3 feet, and were, therefore, not completely representative is size category.

Tables XXI and XXII show that the numbers of halibut on the affected grounds, exhibiting some e of infestation, however slight, are greater than indicated by investigations on gutted fish on the deen market. It is fortunate, however, that the heaviest infestation is borne by those organs within ody cavity which are discarded in gutting. Although the numbers of halibut displaying infestation e body cavity and of the flesh would appear to be roughly similar, Table XXII shows that the e of infestation of the body cavity is on the whole greater than in the flesh. It is concluded, there- that inspection of the body cavity serves as a reliable, though not infallible, first means of recognising ble infestation of the flesh on the market. In the light of experience this method, reinforced in doubt- ases with judicious incisions with a knife in the flap region has proved remarkably successful in ice.

The remaining thirteen halibut caught by the research vessel on west Icelandic grounds were ined in the same way. Although one or two cysts were found in the mesenteries or organs of a f these fish none was identified as *Grillotia*. No cysts were found in the flesh in this case.

DISTRIBUTION OF THE PARASITE IN THE NORTH ATLANTIC

Dollfus (1942 and 1953) states that the encysted plerocercoid larva of *Grillotia erinaceus* is known more than thirty species of teleost fishes along the coasts of Europe from Murmansk to the Mediter- n and from an even larger number of fishes along the eastern coast of the U.S.A. According to the writer the adult worm has been recognised in twenty-three different species of elasmobranchs from pean and North American coastal waters.

Published records emphasise the coastal nature of the parasite's distribution but Rees and Llewellyn) have demonstrated the presence of both larval and adult forms in fishes from the Irish Atlantic and Porcupine Bank at depths of 150 to 200 fathoms. Following the discovery of the heavy infesta- f halibut by cestode larvae on Rockall Bank and other grounds a search was made for adult cestodes e alimentary canal of skates, rays and dogfishes from these grounds. Adult specimens of *Grillotia eus* were found in some cases, along with other worm parasites, in the spiral valve of four species ia—*R. batis*, *R. oxyrhynchus*, *R. circularis* and *R. clavata* from Rockall Bank and north-west Scottish nds. On this occasion *R. batis* was the commonest species of *Raia* and it is interesting to record that rth-west Scottish grounds three out of the ten specimens of this fish examined contained adults *illotia erinaceus* whereas on Rockall Bank eight out of thirteen fish were parasitised by this worm. suggests a heavier infestation of *Raia batis* by the adult worm on Rockall Bank than off the north- of Scotland—a feature which seems to be consistent with the degree of larval infestation of halibut e same grounds. Adult specimens of *Grillotia erinaceus* were also found in the spiral valve of two out ree dogfishes, *Squalus acanthias*, caught on the edge of the deep water west of the Shetlands.

The present observations therefore extend the known area of distribution of this parasite still further nd the coastal zone to the oceanic banks between Scotland and Iceland where infested halibut are nt at depths exceeding 200 fathoms. Indeed it has been noted that in at least two areas, north- Scotland and Rockall Bank, halibut inhabiting deep water tend to be more heavily parasitised those on the shallower grounds. Despite this addition to the knowledge of the distribution of *Grillotia*

erinaceus the area in which this cestode is parasitic in halibut is less extensive than the area in which found in other species of fish. For example no evidence has so far been obtained of its occurre halibut from the American and Norwegian coasts where it has been recorded from other fishes.

TABLE XXIII

Halibut food frequencies 1923-38 and 1952-57

Region	North Sea and Scottish NW Coast		Faroe		Rockall, Lousy, Rosemary, Butt of Lewis	Iceland		East Greenla
Size Range	21-50 cm	51-193 cm	<21 cm	21-50 cm	51-189 cm	84-156 cm	21-50 cm	51-177 cm	>90 cm
Number of stomachs examined	14	67	8	182	42	46	168	57	27
Number of empty stomachs	1	17	—	38	10	19	45	17	12
Number with recognisable food	13	50	8	143	32	27	121	40	15
Pisces	8	33	2	71	25	26	93	31	14
Ammodytes sp	6	2	2	28	4	—	61	1	—
Gadus aeglefinus L.	—	3	—	2	—	1	—	1	—
Gadus merlangus L.	1	8	—	1	1	—	1	—	—
Gadus esmarkii Nilsson	—	—	—	5	1	—	—	1	—
Gadus callarias L.	—	1	—	—	—	—	—	—	1
Gadus poutassou (Risso)	—	—	—	—	—	2	—	—	—
Brosme brosme (Müller)	—	—	—	—	1	2	—	—	—
Gadus sp	—	—	—	3	1	2	5	4	—
Limanda limanda (L.)	—	1	—	1	—	—	—	—	—
Hippoglossoides platessoides (Fabricius)	—	1	—	—	1	—	—	3	—
Pleuronectid ? sp	—	2	—	—	—	2	—	4	—
Clupea harengus L.	—	2	—	1	—	—	—	—	—
Scomber scombrus L.	—	2	—	—	—	—	—	—	—
Pholis gunnellus (L.)	—	—	—	2	—	—	—	—	—
Agonus cataphractus (L.)	—	1	—	1	—	—	—	—	—
Pagellus centrodontus (De la Roche)	—	—	—	—	—	1	—	—	—
Merluccius merluccius (L.)	—	—	—	—	—	1	—	—	—
Argentina sp	—	—	—	—	—	2	—	—	—
Sebastes sp	—	—	—	—	—	—	—	2	5
Anarhichas lupus L.	—	—	—	—	—	1	—	2	—
Gobius sp	—	—	—	2	—	—	—	—	—
Triglops pingeli Reinhardt	—	—	—	1	—	—	—	—	—
Cottus sp	—	—	—	1	—	—	—	—	—
Mallotus villosus (O. F. Müller)	—	—	—	—	—	—	1	5	—
Onos cimbrius (L.)	—	—	—	—	—	—	—	1	—
Lumpenus sp	—	—	—	—	—	—	—	3	—
Crustacea	5	14	8	103	7	2	47	19	1
Decapoda ? sp	3	12	3	80	5	2	5	4	1
Hyas sp	1	2	1	12	4	1	7	2	—
Portunus sp	2	2	—	9	3	1	5	2	—
Munida sp	—	1	—	4	—	—	—	2	—
Pandalus sp	—	—	5	32	—	—	22	1	—
Crangon sp	—	—	—	3	—	—	2	—	—
Galathea sp	—	—	—	13	1	—	1	—	—
Geryon tridens Krøyer	—	2	—	—	—	—	—	—	—
Nephrops norvegicus (L.)	—	1	—	—	—	—	—	8	—
Eupagurus sp	3	1	1	43	1	—	4	1	—
Spirontocaris sp	—	—	—	—	—		2	—	—
Euphausiacea	—	—	1	—	—	—	1	—	—
Mollusca	1	5	—	6	5	2	1	—	1
Cephalopoda	1	4	—	2	4	2	—	—	—
Loligo/Eledone sp	—	1 L.	—	—	1 E.	—		—	—
Gasteropoda	—	1	—	—	—	—	1	—	1
Lamellibranchiata	—	—	—	2	—	—	—	—	—
Polychaeta (*Aphrodite* sp)	—	1	—	—	—	—	—	—	—
Holothurioidea	—	—	—	—	—	—	—	—	1
Algae	—	—	—	1	—	—	—	—	—

Kahl (1937) and Luling (1951 and 1952) found cestode larvae, which they identified, though rather antly, as the larvae of *Grillotia erinaceus* in large numbers in the flesh of *Sebastes marinus* from the vegian coast. Dr. G. H. O. Burgess of the D.S.I.R. laboratory, Hull, has also described, in a personal nunication, the appearance of plerocercoid larvae resembling those of *Grillotia* in the flesh of *Sebastes us* from Icelandic and Arctic waters. Even if the larvae should be present on the gut of halibut these northern grounds some explanation is required of the large numbers observed in the flesh bastes. It is not yet obvious why the plerocercoid larva of *Grillotia erinaceus* should infest the flesh libut to the extent it does on Rockall Bank and yet not be present in this fish on Norwegian and ndic grounds, where it infests the flesh of *Sebastes marinus* in a marked degree. A possible cause may differences in the feeding of the halibut in the two areas, since it is generally accepted that the mission of the parasite from one host to another is effected through the feeding of the fish. At the time the possibility of specific differences in the *Grillotia* found on the two fishes cannot be dis-ded.

POSSIBLE METHODS OF INFECTION

The food of the halibut has been studied on a number of occasions. Scott (1909) examined over a sand stomachs from the North Sea and other undefined grounds. Jespersen (1926) confined his tion to the food of young fish from Faxa Bay. Iversen (1936) made some interesting notes on the ach contents of line-caught halibut off East Greenland. McIntyre (1953), dealing with halibut ht by commercial vessels in Icelandic and Faroese waters, treated the subject in some detail.

Table XXIII summarises notes by the author, hitherto unpublished, on the food of halibut caught ly by the Scottish research vessels during the interwar period and later from 1952 to 1957. These s are in general agreement with those published by others and help to establish the following res of the halibut's food:

a) that fish and decapod crustaceans are the two main types;
b) that small halibut feed chiefly on decapod crustaceans but as they grow bigger they become more dependent on fish;
c) that large halibut are mainly fish eaters although they may continue to eat large decapods and cephalopods.

By the time halibut have grown to a length of 3 feet their diet consists predominantly of fish. It has ly been stated that infestation by the larvae of *Grillotia erinaceus* begins about this size so that it probable that the parasite is acquired through the halibut eating another species of fish.

On the whole the lists of animals eaten by halibut of the same size groups show a remarkable simi- in the different regions. Nevertheless, as may be expected in a species with such a wide distribution iving under varied physical conditions, the lists contain types, particularly among the fish, which naracteristic of certain regions only. Thus Iversen's notes on the food of East Greenland halibut le arctic and arctic-boreal forms such as *Gymnelis* and *Lycodes* which have not been recorded in od from other areas. McIntyre demonstrates the importance of redfish, *Sebastes marinus*, in the diet ge halibut west of Iceland and Table XXIII indicates the dependence of East Greenland halibut is fish. In the North Sea, at Faroe and on certain Icelandic nursery grounds, sandeels are the main ype in the food of the smaller halibut while gadoids, flatfishes and clupeoids occur more frequently stomachs of the larger fish. Table XXIII also shows that the food of halibut on Rockall Bank and jacent grounds includes several species with a southerly distribution. These include the common ream, *Pagellus centrodontus*, hake, *Merluccius merluccius*, and blue whiting, *Gadus poutassou*, each of has a more southerly centre of distribution than the other species which contribute to the food halibut. It seems reasonable to assume that other southern species, particularly among the deep pelagic types, are also eaten by halibut on Rockall Bank and neighbouring grounds. The differ- in the food of halibut from one region to another seem to provide a possible explanation of the ation by *Grillotia* on certain grounds.

The completion of the life cycle of the parasite from the adults in elasmobranchs to the plero larvae in halibut and other teleosts requires the presence of another host. Johnstone's view that th larval life of the parasite is spent in some invertebrate has since been confirmed experimenta Ruskowski (1934) who described his successful efforts to rear this stage, the procercoid, in ca copepods. Ruskowski concluded that the life cycle is advanced by a fish eating the copepod thus en the development of the procercoid to the plerocercoid. This is a reasonable conclusion but it is inad in the present instance since the halibut does not feed on copepods, except possibly in its post period. Moreover infestation by *Grillotia* does not occur until years later when the halibut is 3 feet in length. Two explanations appear possible:

1. that the procercoid stage of the parasite exists in another invertebrate of a larger size copepod and particularly in one which is eaten regularly by halibut.
2. that the copepod is eaten by a small fish such as a young blue whiting or scopelid, which is eaten by a halibut before the parasite has had time to resume its development beyo procercoid stage.

The possibility, however, of a large invertebrate acting as an alternative primary host to an a parasitic in copepods seems remote, on the grounds of size and general habit. The predomina fish in the diet of large halibut on the other hand suggests that the latter explanation is the more pr of the two.

Discussing the life history of *Grillotia erinaceus* Johnstone concludes that it is unlikely that ra infected by eating teleost fishes containing encysted plerocercoid larvae, since this is not suppor an examination of their food which he points out is largely crustacean in character. However, the au recent investigations of the food of the Raiidae show quite conclusively that Johnstone's view i curate and that many species of this family, and especially the larger individuals, prey almost excl on fishes. Johnstone also arrives at the conclusion that the halibut, like all other teleosts, is a fin not an intermediate host, although he recognises that the development of the parasite cannot p beyond the plerocercoid stage. In his view the encysted parasite in the tissues of halibut and other has entered a cul-de-sac in its development in which it ultimately dies. This theory, however, d explain how the parasite can proceed from the procercoid stage in the invertebrate to the matur in the rays without passing through the plerocercoid phase which is found in teleosts. Furthern calanoid copepods alone are the hosts of the procercoid stage, direct transmission to the adult unlikely since skates and rays do not eat copepods except, perhaps, during the early months c existence.

It would appear therefore that the plerocercoid stage in teleosts is an essential part of the life of this parasite and not a blind termination as Johnstone suggests. It seems likely too that the pres the plerocercoid larvae in large fish such as the halibut can only be explained by the assumptio the copepods carrying the initial larval phase are first eaten by a small fish which in turn is eaten halibut before the larvae have had time to progress beyond the procercoid stage. Although the pr of the plerocercoid larvae in large halibut may, in a restricted sense, be regarded as representing a c sac in the development of the parasite, since skates and rays are unlikely to eat these fish, it must be in mind that certain large sharks such as the Greenland shark, *Somniosus microcephalus*, the six-gilled *Hexanchus griseus*, and possibly the porbeagle, *Lamna cornubica*, prey upon halibut. So far the adult C has not been recorded from these fish but its presence in *Squalus acanthias* in Scottish waters sugge possibility of its occurrence also in the larger sharks.

OBSERVATIONS ON THE USE OF WORM-INFESTED FISH IN THE TRACING OF STOCK MOVEMENTS

Tåning (1936) has expressed the view that halibut spawn in the North Atlantic at depths o metres or more. Although few eggs or larvae have been found in the plankton collections by re vessels it is recognised that the nursery grounds for the young fish during the first few years of th

he shallow or comparatively shallow water of the oceanic or coastal banks. It is clear therefore
: life history of the halibut must involve movements of considerable extent in some cases—firstly
e drift of larvae with the water currents from the deep water to the shallow banks and secondly
tary movement of adolescent fish from the banks to the deeper water. There is evidence from the
investigations that adolescent fish do not mix to any great extent with adult fish and confine
ves on the whole to depths of less than 100 or 150 fathoms. This is exemplified by the predomi-
adolescent stocks of Faroe and Bill Bailey's Banks as well as of certain parts of the Faroes and the
Sea. After spawning the halibut again seek comparatively shallow water for feeding although
ly few return to the nursery grounds for this purpose. Most of the adult stocks appear to maintain
ate deep-water existence feeding on the deeper banks but seldom encroaching on the grounds of
nger fish.

gging experiments have demonstrated some remarkable movements or migrations by individual
ning (1938) records the movement of four young halibut from the Faroes to Iceland and of a single
n the Faroes to the North Sea; the capture of a Canadian tagged halibut by an Aberdeen liner
west coast of Iceland in December 1953 has revealed an exceptional movement of over 1600
y the shortest route from Anticosti Island in the Gulf of St. Lawrence (McCracken, personal
nication).

om the results described in this paper consideration has been given to tracing the movement of
from the records of worm infestation. Obviously this can only be applied to adult fish since
sation by *Grillotia* is of little account in immature and adolescent fish.

e absence of worm cysts from the body cavity and flesh of large halibut caught in the north-
North Sea is of some interest since these fish have moved into the area to feed. Furthermore, on
dence of the capture of similar fish to the west of Orkney and Shetland and particularly of those
y small vessels at both the east and west entrances to the Pentland Firth and in the vicinity of
rgh Head, Shetland, many of the immigrants to the North Sea would appear to come from the
n the other hand it seems possible that some of the North Sea fish in the Viking Bank area come
om the Norwegian Sea. It is also possible that immigrants come from the region of the deep water
h the Butt of Lewis and Flugga where infestation is very slight.

already indicated, records of infested fish were rare from the relatively shallow grounds within
ngle formed by Flugga, Butt of Lewis and the Pentland Firth. These few were obtained from the
of Sule Skerry and from positions 25′ N.W. of Noup Head and 15′ W.N.W. of Flugga and
nt the most easterly records obtained. The evidence therefore suggests that these infested fish
eastwards from affected areas situated to the west.

ference has already been made to the annual great-line fishery north-west of the Butt of Lewis
l and May. This fishery varies from year to year. In the five years under review the best results
hieved in 1954 and the poorest in 1956. In the former year worm infestation of the body cavity
its highest level but in the latter no trace of cestode larvae was found in any of the fish (Table II).
ar that the success of this fishery depends on an influx of large adult halibut from deep water
the Shelf. The absence of infested fish in 1956 indicates the possibility that parasitisation of halibut
otia erinaceous is not indigenous in the Butt of Lewis area. At the same time the low proportion of
fish on these grounds in other years shows that the invading shoals are not entirely of the same
s those which give rise to the Barra Head and Rockall Bank fisheries. While some of the halibut
off the Butt of Lewis may come from the direction of Faroe or Faroe Bank, where the proportions
ed fish are similar, that does not rule out the possibility that a few fish may have migrated north-
ds from more heavily infested grounds such as Barra Head, or perhaps even from Rockall Bank.
uld account for the moderate degree of infestation in some of the halibut caught off the Butt of
n 1954; on the other hand the complete absence of heavily infested fish throughout the five years
to indicate a more limited migrational movement.

ile considering the results of the market inspection of halibut from the oceanic banks attention
n drawn to the variable annual and monthly proportions of infested fish on the different grounds
n on the same grounds. The possibility of this being wholly due to different topographical or
features in the case of Rockall Bank has been regarded as unlikely for two reasons:—

1. the main halibut stocks visit these banks seasonally for feeding purposes and a certain am mixing of stocks seems probable in the surrounding deep water.
2. conditions on the smaller banks are fairly uniform yet variations in the proportions of i fish occur on each.

Differences in the numbers of the procercoid stage of the parasite produced every year undoubte has an effect on the numbers of affected halibut, although annual variation is masked to some ex the cumulative nature of the infection. The story of the infestation of the halibut is made diffi inadequate knowledge of the complete life-history of the parasite.

Despite the variable proportions of infested fish the results show a characteristic range for eac from the most heavily affected, Rockall Bank, to the least affected, Faroe Bank. This suggests t stocks of halibut frequenting each bank during the feeding season are more or less restricted t particular localities although some mixing of stocks through migration may account in some parts variations observed on the different banks. Both migration and mixing of stocks appear to vary tensity from time to time. It seems reasonable to conclude, therefore, that the extraordinarily hi portions of infested fish observed on Lousy, Bill Bailey's and Faroe Banks in the summer of 1956 r from either an exceptionally thorough mixing of stocks during spawning in the deep water to th or from the northwards migrations of unusually large numbers of fish from the region of Rockall At the same time the numbers of infested fish may have been increased by the appearance of numbers than usual of the early stages of the parasite.

With the exception of one lightly infested fish caught in the Loon Deeps, off South-east Ic none of the six thousand halibut examined from Icelandic waters was found to be parasitised by *erinaceus*. This is most unexpected when one takes into account the relatively short distance betw oceanic banks or Faroe and the nearest Icelandic grounds and the fairly high percentage of infes on some of the banks. It seems clear that very few adult halibut migrate from the oceanic banks to I Although it cannot be stated with any assurance that young halibut do not move in the reverse di the evidence from a study of worm infestation and of the general appearance of the catches sugg existence of separate stocks.

Despite the seasonal movements of halibut in the North Atlantic for feeding and spawning p this study of the infestation of the species by larvae of *Grillotia erinaceus* suggests that the fish are g regionally in a number of different stocks. Although it seems probable that some mixing of stoc place at spawning time for example, there appears to be little or no mass interchange of fish. Th clusion is based on the assumption that parasitisation by the larvae of *Grillotia* is indigenous to eac grounds on which it has been detected, but even if infestation in the lightly affected peripheral regarded as being due to immigration this would still imply the movement of only a small percen the total stocks. Spectacular migrational movements by individual fish, such as have been demon by tagging experiments, would appear to be the exception rather than the rule. The existence of s local stocks also seem to be supported by the assertion of experienced great-line fishermen that from individual grounds such as Barra Head, Rockall Bank, Lousy Bank and Iceland may be rec from the general appearance of the fish. Differences, for example, in the size and girth and in the of both upper and lower sides of halibut certainly tend to support that view.

NOTES ON THE OCCURRENCE OF OTHER INTERNAL PARASITES IN THE HALIBUT

The plerocercoid larvae of *Grillotia erinaceus* appear to be overwhelmingly the most numerous p in the halibut. Although no special search was made two other types of internal parasite were rec in the course of the investigations. These were (*a*) larval ascarid nematodes, and (*b*) post-larval spe of the cestode *Hepatoxylon trichiuri* (Holten).

Larval nematodes were not infrequently observed encysted in a neat coil within the body In most cases the worms were found on the surface of the liver (Figure 6) and on the mesenteric

asionally they were present on the surface of the gonads or immediately below the peritoneum of ty. In two exceptional instances larval nematodes were discovered within the flesh of halibut. In of these, three worms were coiled in the flesh near the base of the anal fin of a fish, four feet long, west of Myggenaes, Faroe, in September 1953. On the second occasion a single nematode was the flesh of the 'flap' surrounding the body cavity of a fish, 4 ft. 8 in. in length, caught on Rockall October of the same year. It is perhaps appropriate at this point to refer to the tendency for the flatfishes from certain grounds to be heavily parasitised by larval cestodes but very infrequently al nematodes, while the flesh of gadoids on the other hand is heavily parasitised by larval nema- ut rarely by larval cestodes.

st-larval specimens of the cestode *Hepatoxylon trichiuri* were conspicuous in a relatively small number halibut examined. From one to four specimens were observed within the body cavity of thirty- but although no doubt many others may have been discarded during the gutting of the fish. A few parasites were adhering to the remains of the mesenteric filaments surrounding the gut and in the worm was found on the surface of the ovary, but in the majority of the fish they were located osterior end of the body cavity, in the angle formed by the junction of the rectum and the wall avity. Most of these post-larval worms were dead and quite brittle as a result of calcification of ues. Those gathered at the rear end of the cavity were invariably dead and calcified as if they had backwards after death. The condition of these parasites provide further confirmation of Johnstone's hat larval cestodes, if denied the opportunity of further development, die and become calcified he tissues of their host.

indication of the distribution of this cestode is derived from the grounds on which their halibut ere captured. Twenty-one of the thirty-five fish were taken on Rockall Bank, two on north-west ounds, one north-west of the Butt of Lewis, one on Rosemary Bank, three on Faroe Bank, one on ley's Bank, two on Lousy Bank and four on south Icelandic grounds. This distribution is similar of *Grillotia erinaceus* even to the extent of the somewhat heavier concentration on Rockall Bank. r records from south Icelandic grounds, however, indicate that this worm is rather more numerous *illotia erinaceus* in the halibut of this region. At Iceland records of *Hepatoxylon* were obtained from s as far apart as south-west of Ingolfshofdi Huk, the Skedara Deep (2 fish) and the Beru Deep. rasite has also been recognised in the body cavity of saithe, *Gadus virens*, from southern Icelandic . It was not found in any of the fish from west Icelandic grounds. No indication was obtained he present investigations of the presence of *Hepatoxylon* in the flesh of halibut.

E ON THE RELATIONSHIP OF THE INFESTED FISH TO THE TOTAL HALIBUT CATCH BY SCOTTISH GREAT-LINE VESSELS

ring the years which followed the end of the second great war the great-line fishery from Aberdeen ed rapidly to provide a peak landing of over 91,000 cwt of halibut in 1950. In the next five years, r, a rapid decline took place until, in 1955, the halibut catch by great-lines had fallen to one-fifth 950 total. This decline was due partly to a growing difficulty in locating halibut and partly to osts of production which caused fishermen to abandon lining in favour of the more profitable g. The average yearly landings of line-caught halibut in Scotland (almost entirely at Aberdeen) five years 1951-1955 from each of the five regions listed in the statistics published by the Scottish Department are as follows:

tistical egion	North Sea	West of Scotland	Faroe	Iceland	Greenland
ght, cwt	2838	2194	6576	21279	2899
f total	7·9	6·1	18·4	59·4	8·1

All the banks and grounds from which worm-infested halibut normally come are included statistical regions of West of Scotland and Faroe. On an average, therefore, 8,770 cwt or 24·5 total Scottish landings by great-liners came under suspicion of being worm-infested every ye been shown, however, that infestation in fish of less than 3 feet in length is negligible and that fish the percentage of those affected varies considerably according to the location of the fishing Since the landings from each individual bank or ground are not available a detailed calculat quantity of fish actually affected by the parasites is not possible. On the basis, however, of the d in Tables II to XI, and having regard to the size composition of the catches on the different a rough estimate shows that from 10 to 20 per cent of the total quantity of line-caught halibu west of Scotland and Faroe statistical regions is affected in some degree. This represents from cent of the total Scottish great-line catch of halibut from all regions. It is obvious that the gr of this percentage is affected only in a very slight degree and that the numbers (see Table weight of the fish liable to be condemned are in effect relatively small. Nevertheless the elim halibut with serious infestation of the flesh by means of market inspections is a safeguard whi sidered essential from all angles of the fish trade.

SUMMARY

Halibut on certain north-east Atlantic grounds are parasitised by encysted plerocercoid the cestode *Grillotia erinaceus* (van Beneden). The most seriously affected areas are Rockall grounds to the west of Ireland and to the west of Barra Head, Scotland. Halibut from northern stretching from the North Sea westwards through north Faroe and Iceland to Greenland (ex single record from south Iceland) are free from infestation.

Young, immature or 'chicken' halibut are not affected. Infestation is slight in fish of less t in length. On the whole the degree of infestation is greater in the older and bigger fish.

The larval parasites may occur in any part of the fish. The heaviest concentration of cy the outer wall of the stomach, on the mesenteries of the body cavity and on the surface of the lining of the body cavity may also be affected. In general the higher the degree of infestation c cavity the greater is the possibility of the parasites being present in the muscle tissues or flesh been adopted as a guide in market inspections.

All halibut over 3 feet in length from the affected grounds are now examined prior to the of the fish. Fish suspected of being seriously parasitised in the flesh are detained for closer ex and are subsequently condemned if considered unfit for human consumption because of thei appearance.

The distribution of the parasite in halibut and in other food fishes throughout the north discussed. Consideration is given to the possible method of infection. Reference is made to t the halibut and attention is drawn to the differences in the species of fish consumed from one another.

The use of worm-infested fish in studying the location or movements of halibut stocks is di

About a quarter of the total landings of halibut by Scottish great-line fishing vessels c Rockall Bank and other affected grounds. Roughly from 10 to 20% of the fish from these infested in some degree. This represents from 2 to 5% of the total Scottish great-line catch percentage only a small number of fish are so seriously affected as to be condemned. Never considered desirable that this small number should be eliminated from the halibut landings now being satisfactorily achieved.

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